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(54) [Title of the Invention] Quadrupole mass filter

(57) [Abstract]
[Purpose] To more freely and sufficiently compensate for specification and assembly error in a quadrupole, and to obtain new data.
[Constitution] Voltage-generating circuits 15-18 are provided separately for each of the 4 electrode rods 11-14, and intensity of DC component U, wave height V of AC component V cos ($\omega t + \theta$), frequency ω and/or phase θ are independently varied in relation to each of the electrode rods 11-14 by means of quadrupole control unit 19.

[Scope of the Claim]
[Claim 1] A quadrupole mass filter characterized in that it comprises 4 electrode rods arranged in a position of rotational symmetry around and parallel with the central shaft; a quadrupole mass filter that allows only ions of a specific mass to pass through by means of applying DC and AC superposition voltage between the two pairs of electrodes facing each other across the central shaft, and provided within said filter circuits generating said superposition voltage for each of the 4 electrode rods.
[Detailed description of the invention]
[0001]
[Industrial field of application] This invention concerns a quadrupole mass filter for quadrupole mass filter analysis devices used in the analysis of medicines, foods and environmental substances.
[0002]
[Prior Art] As shown in Drawing 3, the quadrupole mass filter is provided with quadrupole 10, comprising 4 electrode rods 11, 12, 13 and 14 arranged in parallel to each other and in rotational symmetry around shaft z. In quadrupole 10, two electrode rods 12 and 14 are arranged in the direction of axis x as one pair, the other pair comprising electrode rods 11 and 13 arranged in the direction of axis y, and DC voltage U and high frequency current V cos (ωt) are applied as superposition voltage between the two pairs of electrodes (12,14) (11,13). When various ions are injected from one end of shaft z, being the central shaft in quadrupole 10, in general they are dispersed outward from quadrupole 10 due to the oscillating electric field formed by this voltage. However, when DC voltage U and AC voltage V are in a fixed relationship determined by the mass/charge number (m/z) of the ions, only ions with this mass/charge number oscillate in a stable manner and can be emitted from the other end of shaft z. Therefore, by positioning an ion detector at the exit of quadrupole 10 and setting the voltage applied to quadrupole 10 at an appropriate level, a mass filter that only allows ions of the desired mass to pass through can be constituted. As shown in Drawing 4, the U / V region in which ions are able to pass through quadrupole 10 forms a truncated triangle, and as m/z = M1 / M2 / M3 changes, the stable region shifts as shown in the drawing. Therefore, by varying U and V as represented by line L, ions passing through the mass filter can be scanned.
[0003] Drawing 3 (a) shows a specific example of the circuit generating DC/AC superposition voltage to each of the electrode rods 11-14 in quadrupole 10. In this example, in addition to circuit 31 generating DC voltage U and circuit (HF) 32 generating high frequency voltage V cos (ωt), perturbation voltage application circuit 33 is provided separately from HF 32, applying supplementary low-amplitude AC voltage (perturbation voltage) Va at a different frequency to HF32. By applying this perturbation voltage, the resolution of the mass analysis can be enhanced (for details, see Unexamined Patent Application Publication 4-218251), but this supplementary circuit is not essential and may also be omitted. Furthermore, the circuit in Drawing 3 (a) is represented in simplified form in Drawing 3 (b)
[0004]
[Problem to be solved by the invention] It is desirable for the specifications of each of the electrode rods 11-14 in quadrupole 10 to be strictly identical, and their relative positions to be strictly in rotational symmetry and parallel to each other, but in practice it is difficult to achieve this kind of assembly. Moreover, electrode rods 11-14 are fixed in a pair of ceramic holders, but when the high frequency (approx 1MHz) described above is applied to them, dielectric damage to the ceramic holder occurs and heat is generated. Expansion and distortion of the holders due to this heat also causes the relationship between electrode rods 11-14 to change.
[0005] When faced with this situation, in conventional quadrupole filters adjustment was carried out principally by altering wave height value V of the AC component, but this did not necessarily compensate sufficiently enough for error in quadrupole processing and assembly, leading to such problems as reduction in mass resolution and sensitivity.

[0006] This invention was created in order to solve this kind of problem, and its purpose is to provide a quadrupole filter that can more freely and sufficiently compensate for assembly error.

[0007]

[Means to solve the problem] This invention, which was created in order to solve the problem described above, is characterized in that it comprises 4 electrode rods arranged in a position of rotational symmetry around and parallel with the central shaft, a quadrupole mass filter that allows only ions of a specific mass to pass through by means of applying DC and AC superposition voltage between the two pairs of electrodes facing each other across the central shaft, and provided within said filter circuits generating said superposition voltage for each of the 4 electrode rods.

[0008]

[Action] Because voltage-generating circuits are provided for each of the electrode rods, DC / AC component intensity ratio, AC component frequency and wave height can be varied for each of the electrode rods, and phase contrast can be set between the electrodes. By varying these numerous parameters as appropriate, quadrupole adjustments can be carried out to a greater extent than before, and it becomes possible to compensate for assembly error to a finer degree and in an optimum way. Moreover, by detecting passing ions whilst varying the parameters separately for each electrode rod, greater knowledge than before can be obtained in relation to the components and structure of the sample.

[0009] Furthermore, the quadrupole filter of this invention can also be used in MS/MS mass analysis devices with first stage and second stage quadrupole filters, as well as in standard quadrupole mass analysis devices with only a first stage filter.

[0010]

[Embodiments] Drawing 1 shows an embodiment of the quadrupole filter of this invention. In the quadrupole filter, electrode rods 11-14, which make up quadrupole 10, are each provided with one of the voltage-generating circuits A-D (15-18). Each of the voltage-generating circuits 15-18 are similar to those used in conventional quadrupole filters. For example, Drawing 3 (a) shows [a quadrupole] with a perturbation circuit, but this can also be left out, as outlined above.

[0011] Each of the voltage-generating circuits 15-18 independently apply DC/AC superposition voltage of DC component U and AC component V cos ($\omega t + \theta$) to the electrode rods 11-14 connected respectively to them. Voltage-generating circuits 15-18 are connected to one quadrupole control unit 19, which sends a separate control signal to each of the circuits concerning DC component intensity U, AC component wave height V, frequency ω and phase θ.

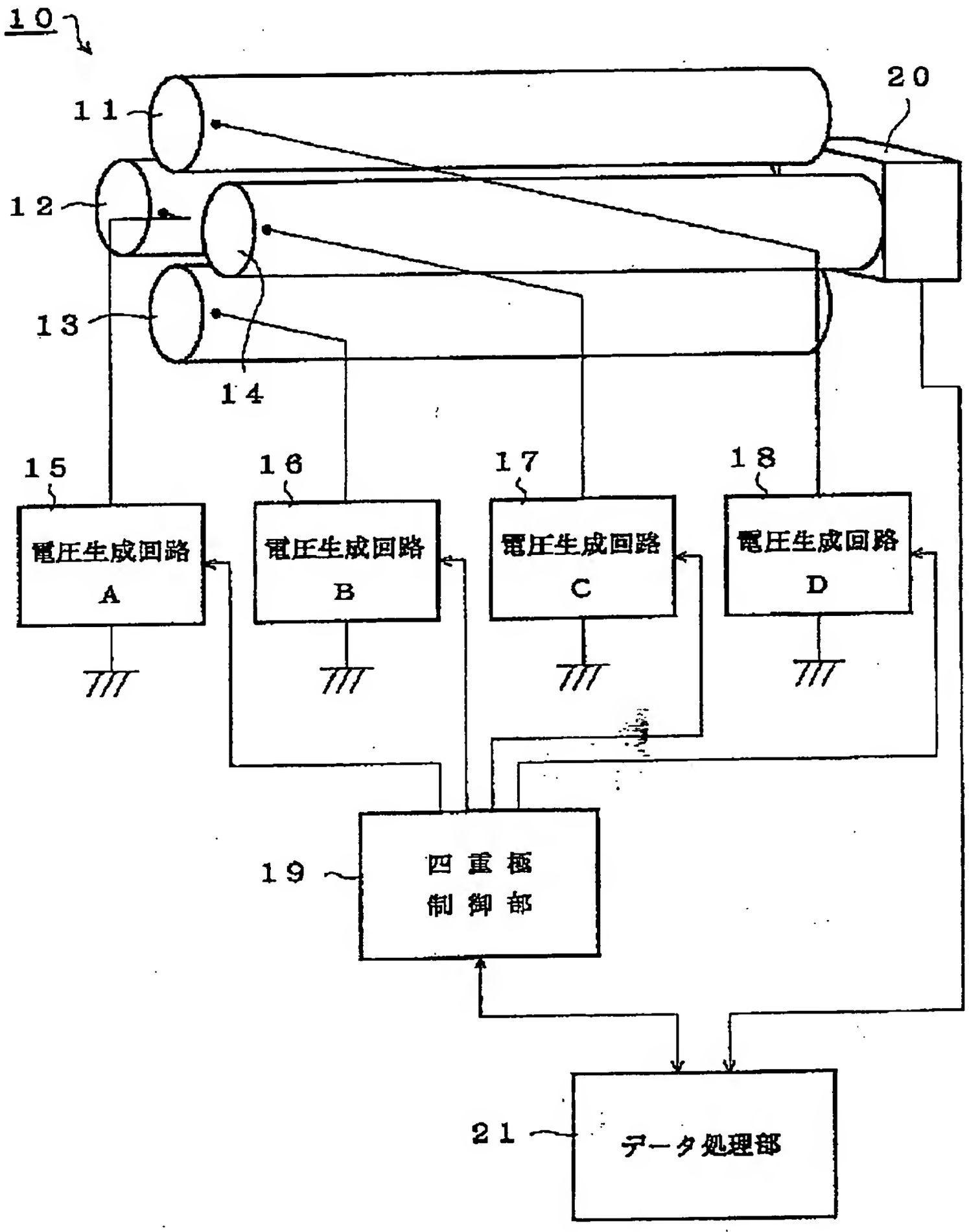
[0012] Ion detector 20 is provided at the exit of quadrupole 10, and its detection signal is sent to data processing unit 21. Based on the ion detection signal and scanning signal from quadrupole control unit 19, data processing unit 21 generates graphs and ion estimations.

[0013] In the quadrupole filter of this embodiment, fine adjustments can be made by varying as appropriate the parameters applied by quadrupole control unit 19 to each of the voltage-generating circuits 15-18, e.g. varying only phase θ of AC component 23 applied to second electrode rod B (12) relative to AC component 22 applied to first electrode rod A (11), as shown in Drawing 2. Drawing 2 shows AC components 24 and 25 with only wave height V (line 3) and frequency ω (line 4) altered, but a combination of waveforms can also be produced as appropriate. By combining these fine adjustments as required, it becomes possible to compensate for specification / assembly error in electrode rods 11-14 and specification / alignment changes in the holders due to heat generation, enabling correct mass analysis to be undertaken. Moreover, by recording changes in ion detection intensity after altering these values, and analysing the data, new information can be obtained relating to the components and structure of the sample.

[0014]
[Effect of the invention] In conventional quadrupole filters, only one voltage-generating circuit was used for 4 electrode rods, but in the quadrupole filter of this invention, voltage-generating circuits are provided for each electrode rod. Therefore, it becomes possible to alter the U/V ratio, frequency of high frequency waves and phase for each electrode rod, enabling finer adjustments than before to be carried out in relation to assembly error etc. Furthermore, by altering the parameters for each electrode rod, various data not achievable in conventional mass analysis can be obtained.
[Brief description of the drawings]
[Drawing 1] An embodiment of the quadrupole filter of this invention, being a simplified component drawing.
[Drawing 2] An embodiment of the quadrupole, being a waveform graph of the AC component applied to each of the electrode rods.
[Drawing 3] (a) A specific example of a voltage-generating circuit in a conventional quadrupole filter and (b) a simplified component drawing thereof.
[Drawing 4] A chart of the quadrupole stable region.
[Description of the reference numerals/letters]

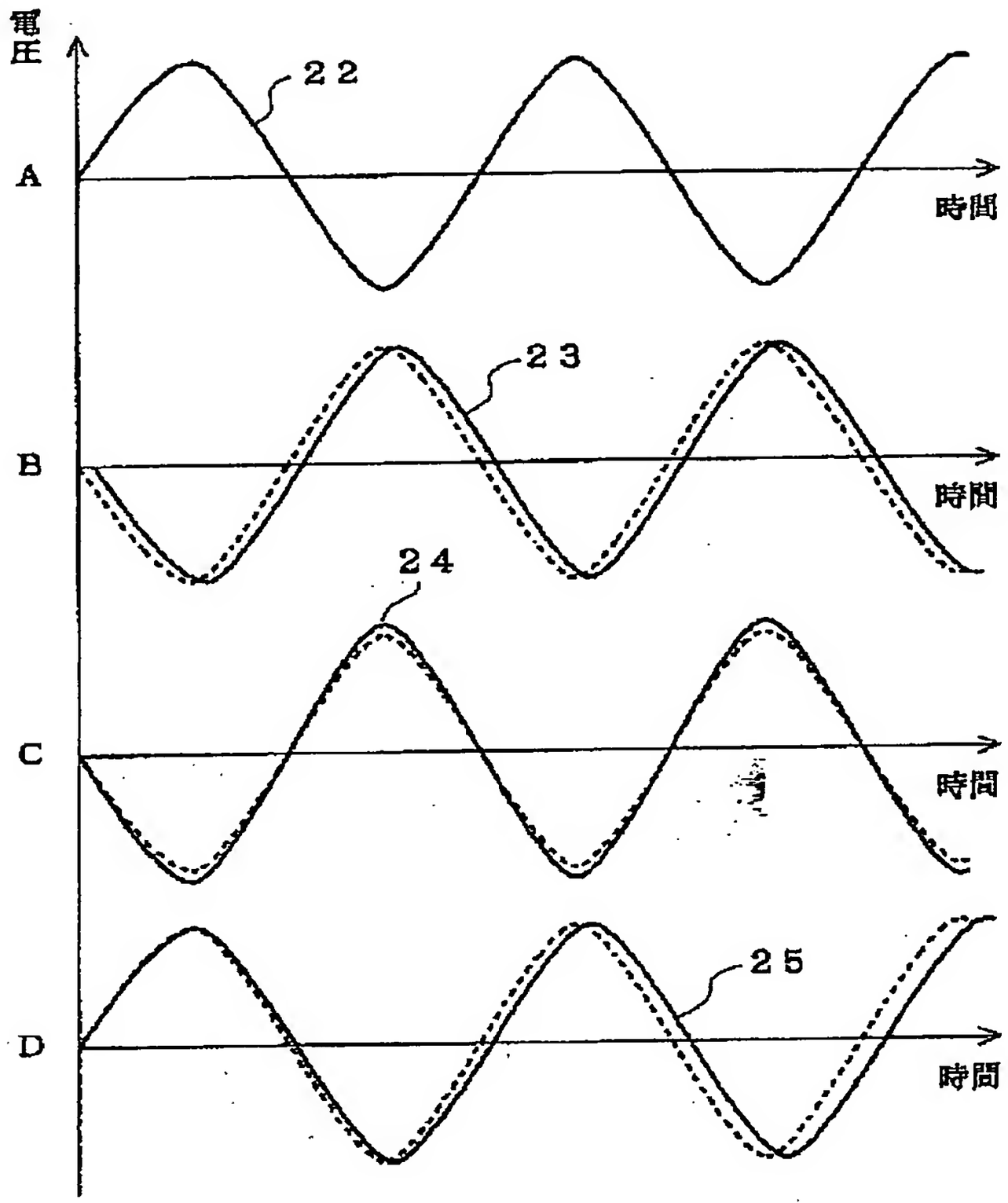
10	Quadrupole
11, 12, 13, 14	Electrode rods
15, 16, 17, 18	Voltage-generating circuits
19	Quadrupole control unit
20	Ion detector
21	Data processing unit

Drawing


10
11
12
13
14
15
16
17
18
19
20
21
電圧生成回路 A
電圧生成回路 B
電圧生成回路 C
電圧生成回路 D
四重極制御部
データ処理部

Drawing 2

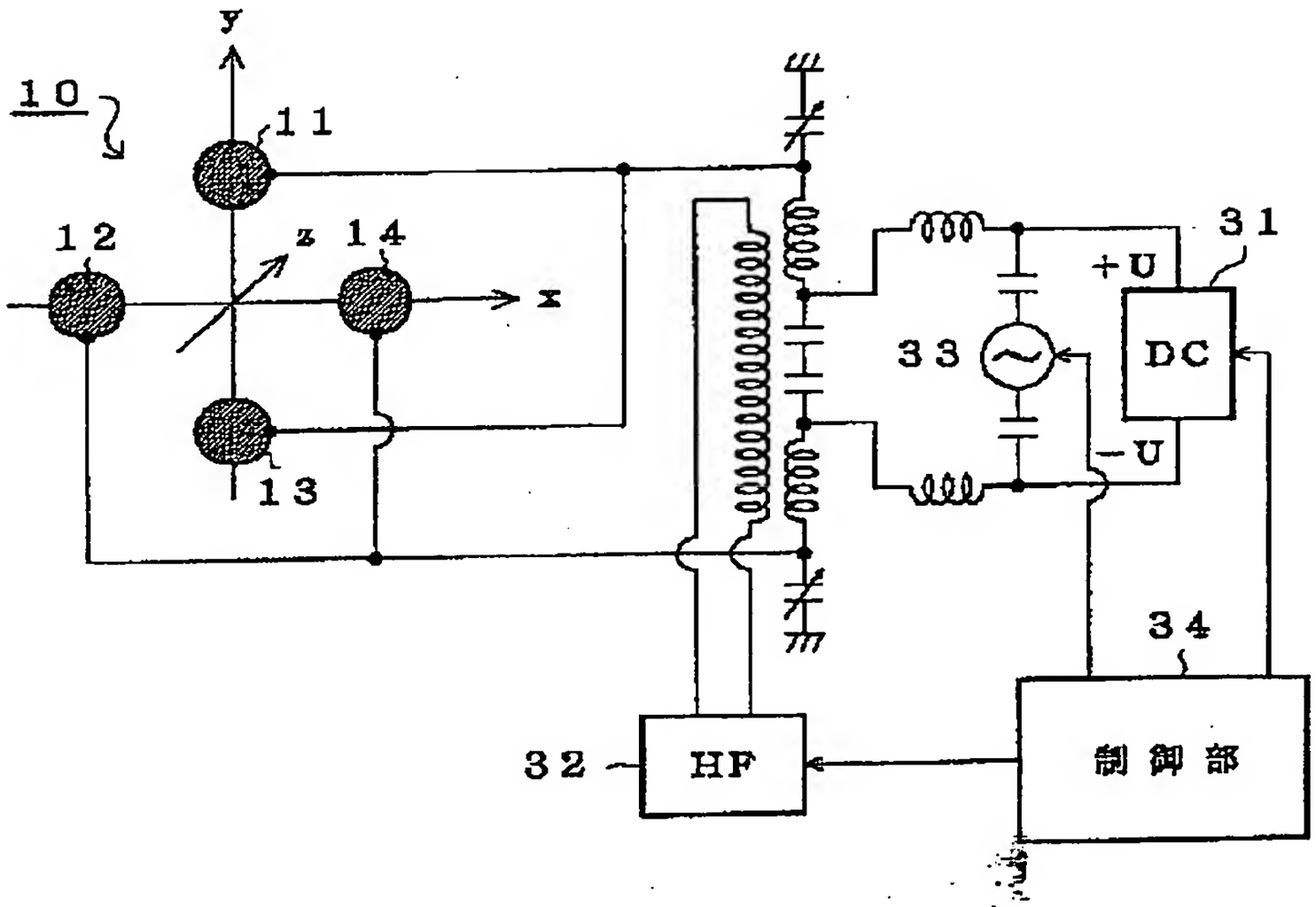
Vertical axis = Voltage Horizontal axis = Time



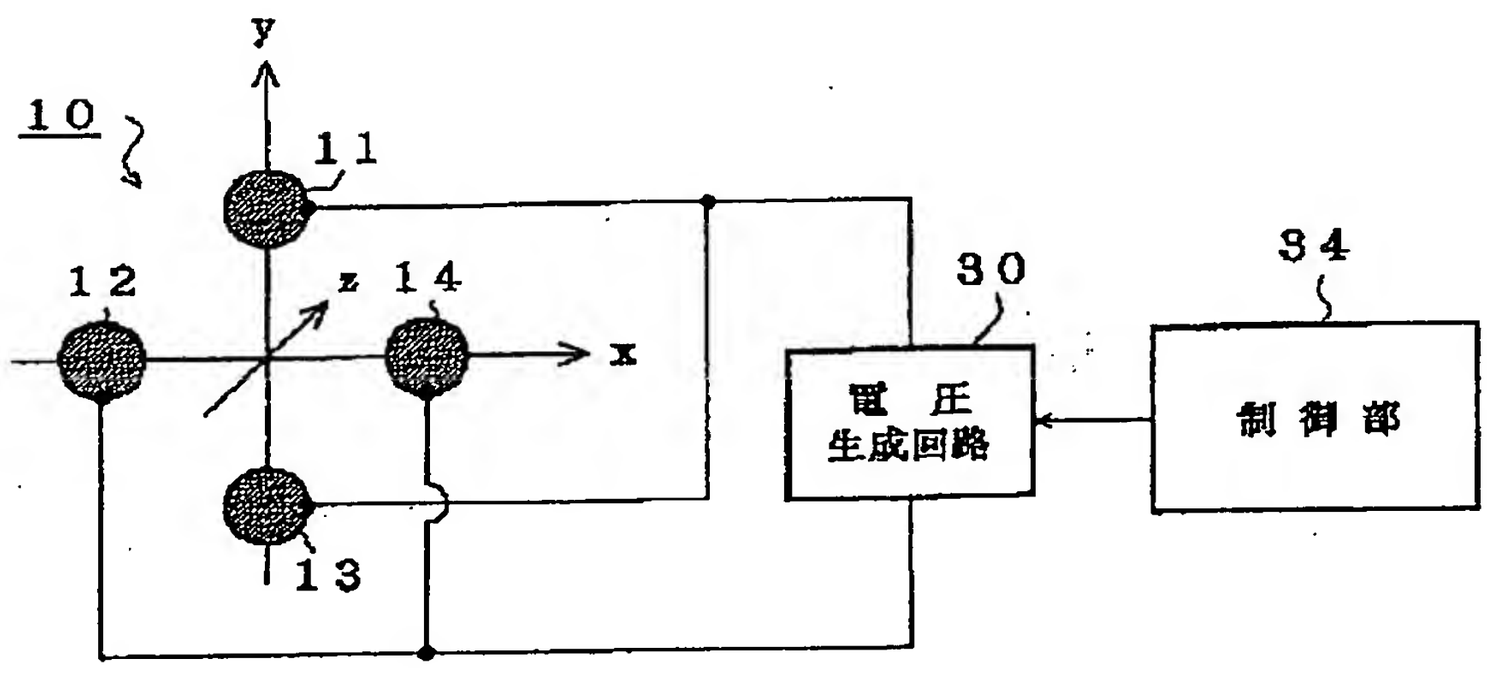
Drawing 3

30 – Voltage-generating circuit
34 – Control unit

(a)



(b)



Drawing 4